What Empirical Research has Established about Wind Farm Visual Impact

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ABSTRACT

The substantial body of empirical research now available on wind farm visual impact (VI), from very credible and impartial teams, shows a consistent and essentially linear relationship between turbine height, distance and wind farm VI. For any degree of VI (such as the zone of visual influence, or threshold for visual dominance), if turbine height is doubled, the distance threshold for that degree of impact also typically doubles.

*The research based distances for thresholds for key levels of VI are **many** times larger than thresholds proposed by the NSW Department of Planning and Environment in its draft VI Assessment Bulletin. **The Department's proposed thresholds are repudiated by the consistent research findings.***

*The research also identifies a number of other ways in which wind farm VI assessment practices accepted by NSW planning agencies are **defective**, in particular relating to the neglected importance of blade movement for VI, the fact that photomontages tend systematically to underestimate VI, and the assessment frameworks commonly used are too simplistic to describe real world experience.*

The NSW Government has a responsibility to reassess its draft VI Assessment Bulletin explicitly in the context of the published research and produce proposals which it can intellectually justify in the context of that research – which at present it cannot do.

Modern wind farms are highly visible structures because of both the height of turbines and their number and geographic distribution in a wind farm. It is common for planning authorities to require some form of visual impact (VI) assessment for proposed wind farms.

Wind farms typically involve a conflict of interests among various parties, on one side the proponents and on the other those who will be affected in various ways by the VI, noise emissions, etc from the wind farm. Predominantly those affected are people who live in some area around the wind farm.

In the early years of wind farm development, there was little empirical guidance for planning authorities as to how VI ought to be assessed. Planners made what no doubt seemed reasonable judgements at the time, to some extent following one another.

However, over time observational and research data relevant to VI policy has been accumulating. Inevitably it has largely lagged wind farm developments, since the most powerful research has depended on the existence of wind farms of particular heights as the observational subjects.

At the same time planners have been subject to growing pressures in this area. Many Governments have decided, as a matter of policy, to encourage wind farms and want to increase their number. Wind turbine technology has been increasing the power and height of wind turbines (now 3 to 4 times what they were a couple of decades earlier) and the economics of wind farm operators encourage them to use these larger turbines. But given the physics of optics, *prima facie* that would suggest even greater VI over wider and wider areas, and thus a stronger basis for rejecting wind farm proposals. If planning processes formally recognise that situation it conflicts with the interests of wind farm proponents and would potentially block many of the wind farms governments have said they want built.

Thus there is real public policy pressure on government officials to construct VI assessment frameworks that diminish the ostensible VI. It creates a conflict between honest and impartial government practices and those created explicitly to serve certain special interests.

The problem for public officials is that attempts to recraft VI assessment frameworks are happening at the same time sufficient consistent, impartial research data has accumulated to provide strong guidance on critical parts of those assessment frameworks.

The NSW Background

In 2011, the NSW Government published draft wind farm guidelines, including some limited guidance on VI Assessment. The Government received community and industry feedback on the proposals and then failed to formalise them. Over the following years, assessments of wind farms took account of those draft guidelines so far as the Department thought appropriate.

In 2016, the Minister for Planning, Robert Stokes, directed the NSW Planning Department & Environment (DPE) to reformulate the wind farm guidelines with the aim of finally formalising them. The Department published new draft guidelines, referred to as a "Wind Energy Framework" in August that year, and made them available for six weeks for comment.

Minister Stokes issued a press release [1] that said a few things about his intentions:

> "A new wind energy planning framework will ensure that NSW has the right settings to attract investment in wind energy, while balancing the interests of the community."

and

> "there will be no arbitrary buffer zones based on the height of turbines"

and

> "The framework strikes the appropriate balance between giving clear guidance to industry whilst ensuring that the impacts of the project are assessed on their merit."

One might reasonably understand from the Minister's statement that he believed the draft guidelines as published were largely appropriate and had the Government's support.

Part of the draft guidelines was a *Visual Impact Assessment Bulletin (VIAB)*. This attempted to codify the VI process to a much greater extent than previously was the case.

The Bulletin included a fairly extensive set of references as the Department sought to demonstrate some validity for its proposed policies. The references included some, though not all, of the research discussed later. For some reason, as will be explained, the policies proposed appeared to make things easier for wind farm developers while being contrary to the very research the Department cited.

They could be seen as fitting with the Minister's apparent desire for more wind farms but certainly not with his claim about "no arbitrary buffer zones based on the height of turbines". Instead the Department produced something that arbitrarily ignored published empirical research on the relationships between turbine height and VI.

Visual Impact Assessment

Visual impact assessment is common in most developed countries for large scale projects such as highways, mines, big industrial structures, and wind farms (which are very large, very high industrial structures over large geographic areas).

In simple terms, VI assessment has two components: how visible is it from a specific viewpoint; and how substantial is the impact on viewers (and how much attention should be given to those viewers)?

This paper focuses on the first part of the assessment structure. It relates essentially to physics and to common aspects of human visual perception. It is this area where research over the last few decades has produced the most important contribution to wind farm VI assessment.

[1] *NEW WIND ENERGY FRAMEWORK TO GIVE CERTAINTY*, Media Release, Rob Stokes, Minister for Planning, 1 August 2016.

The Research

There are many parties that have opinions about distances within which wind farm VI should be assessed. Some of these are private views, others official views encapsulated in regulations, policies and decisions. There are also articles arguing theoretical positions.

Some of the opinions are impartial and some are self-serving. Even the impartial ones are not necessarily well informed. Importantly, almost all of these opinions have lacked any empirical basis.

There are now, however, a number of research studies that remove the need for uninformed opinion in public policy. The studies, over several decades, by a number of individuals and teams are remarkably consistent in their observations. The studies differed in the size of turbines assessed, mainly due to the era in which each study was done. As it happens, the observations of the group of studies collectively show a very strong relationship between turbine height and wind farm VI.

The collective research results are inconsistent with public policy in some jurisdictions and with decisions made by planning authorities without the benefit of that research. Clearly a challenge for public officials is whether they bring policy in line with the substantial research now available or they seek to ignore it and pursue policy contrary to the research results.

Stevenson & Griffiths

The work of Stevenson & Griffiths is summarised in a subsequent report by the University of Newcastle (UK) [2]:

> "Stevenson & Griffiths (1994) carried out a comprehensive post-development audit of eight windfarms in England and Wales, visiting each windfarm on up to four occasions throughout the year. Six viewpoints were analysed at each site at distances up to 20 km, although in practice topography and visibility restricted views from 10 km and prevented views beyond 16 km for all sites. . . . The case study sites included turbines ranging in maximum height from 40.0 to 61.5 (but six were within the range 40.0 – 43.5 m) and in a variety of landscape settings."
>
> "Their main conclusions are that
>
> - In most situations turbines dominated the view up to a distance of 2 km (zone (i)).
> - Turbines appear visually intrusive at distances between 1 and 4.5 km in average to good visibility (zone (ii)).
> - Turbines are noticeable, but not intrusive, at distances between 2 and 8 km, depending on atmospheric conditions and other factors (zone (iii)).
> - Turbines can be seen as indistinct elements within the distant landscapes at distances of over 7 km (zone (iv))."
>
> "For ZVI, they recommend 10 km as suitable in most conditions."

What is noteworthy about the Stevenson & Griffiths research is that it involved eight existing wind farms, each of which was visited on multiple occasions and at different times of the year, and examined from multiple viewpoints. It was a practical and systematic study of what existed on the ground.

Most of the turbines in the wind farms they examined were less than 45m high. The assessments they then made about thresholds for various levels of effect were for wind farms with turbines around that height.

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[2] University of Newcastle (2002) *Visual Assessment of Windfarms Best Practice*. Scottish Natural Heritage Commissioned Report F01AA303A [***University of Newcastle Study***].

The visibility zones identified by Stevenson & Griffiths overlap, reflecting the fact that actual wind farm visibility is influenced by atmospheric conditions, the extent to which terrain conceals part of the wind farm, and other factors. This result is also reported by some of the other empirical studies.

University of Newcastle Study

Published in 2002, this study[3] was undertaken by a team at the University of Newcastle (UK) having been commissioned by Scottish Natural Heritage.

Similar to the Stevenson & Griffiths study, it examined multiple existing wind farms. It involved on the ground assessment of the visual impact of eight wind farms in Scotland. It also evaluated the original environmental assessments for those eight wind farms, comparing the actual visual impact with what had been forecast.

The study team assessed 70 viewpoints, including a total of 113 individual assessments across the eight wind farms. Tip height of the turbines ranged from 53.5 – 85.5 m with the majority 53.5 – 65.5 m. Thus they were generally higher than those examined by Stevenson & Griffiths. The number of turbines in each wind farm ranged from 9 – 46, with an average of 26.

The team reported a number of detailed observations, including:

> "the turbines are perceptible at a range of from 15 – 20 km from the windfarm and up to 25 km in specific cases and conditions"[4]
>
> "Higher turbines are visible over a larger distance"[5]
>
> "In landscapes that were free of man-made elements the turbines were sometimes much more conspicuous in the middle and long-distance ranges and this affected our judgements of their magnitude."[6]

Based on their assessment of the eight wind farms the study recommended a height-distance relationship for ZVI as shown in the following table[7].

Height of turbines (total including rotors)(m)	Recommended ZVI distance (km)
50	15
70	20
85	25
100	30

The study tested the Sinclair-Thomas matrix during its site visits to the eight wind farms. They concluded:

> "In general our onsite assessments were in agreement with Sinclair-Thomas at viewpoints near to a windfarm and at long distances, but we consistently rated the visual effect as either much less or lower in the middle-distance zones, or we were unable to reach a robust judgement because of a lack of differentiation in definition between distance classes."[8]

[3] *University of Newcastle Study*.
[4] *University of Newcastle Study*, p. 51.
[5] *University of Newcastle Study*, p. 51.
[6] *University of Newcastle Study*, p. 54.
[7] *University of Newcastle Study*, p. 58.
[8] *University of Newcastle Study*, p. 61.

The Sinclair-Thomas matrix has 9 zones, with defined distances from the wind farm, with the bounds of each zone being a function of turbine height. So the study confirmed the Sinclair-Thomas categorisation in the lower bands of that system – and this was with wind farms with an average of 26 turbines rather than the larger numbers now common.

Sinclair-Thomas matrix

Gareth Thomas, a planning officer of Powys County Council in Wales, developed an ordinal scale of visual impact from wind farms. He observed and identified the relation between turbine height and distance and the categories in his scale, using wind farms being installed in Wales at that time. Subsequently Geoffrey Sinclair used the same process of empirical observation, and Thomas' framework, to categorise the distance-VI relationship for wind farms with larger turbines. That became known as the Sinclair-Thomas matrix [9].

The matrix and its production are a case of systematic observation by two experienced individuals. Given there were only two involved and the way it was developed, it fits into the hypothesis formation stage of research rather than validation.

However, substantial validation has since been provided by several sources for what are in practical terms the most important parts, i.e. thresholds for the most visually intrusive categories, and for an appropriate distance related ZVI.

The Bureau of Land Management (BLM) Study

In 2012 a report on visual impact of wind farms[10] was released by the well respected Argonne National Laboratory, which is part of the US Department of Energy[11]. The study was commissioned by the US Bureau of Land Management, so is often known as the Bureau of Land Management (or BLM) study.

The research was undertaken by staff in Argonne's Environmental Science Division and involved current and former staff of BLM, including landscape architects.

The study was a systematic examination of the visual impact of five existing wind farms in Wyoming and Colorado, with turbines 90 – 120m in tip height and most of them close to 120m (p. 42). The research involved 377 observations, using multiple observers, at various distances from the wind farms and rating visual impact on each occasion on a 6 point rating scale based on a standard BLM scale adapted to rate existing facilities rather than proposed ones.

The study reported that:

> "Under favorable viewing conditions, the wind facilities were judged to be major foci of visual attention at up to 19 km (12 mi) and likely to be noticed by casual observers at >37 km (23 mi). A conservative

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[9] Apostol, Dean, et. al., *The Renewable Energy Landscape: Preserving scenic values in our sustainable future*, Routledge, 2017 (Google electronic edition), p. 319.

[10] Sullivan, Robert G., et. al., 2012. *Wind Turbine Visibility and Visual Impact Threshold Distances in Western Landscapes*. Argonne National Laboratory and the U.S. Department of the Interior, Bureau of Land Management. USA [***BLM Study***].

[11] The US Department of Energy was certainly not hostile to wind energy. The Obama administration has been very supportive of wind farms. A page on one of the Department's sites stated "The DOE Wind Program leads the nation's efforts to research and develop innovative technologies, lower the costs, and accelerate the deployment of wind power." [http://energy.gov/eere/wind/wind-research-and-development, 20161018]. Note that commitment to "accelerate the deployment of wind power". There is no suggestion of bias in the research observations but, if there were, the disposition of the parent organisation would be to under-rate the visual impact.

> interpretation suggests that for such facilities, an appropriate radius for visual impact analyses would be 48 km (30 mi), that the facilities would be unlikely to be missed by casual observers at up to 32 km (20 mi), and that the facilities could be major sources of visual contrast at up to 16 km (10 mi)." [12]

The study classed situations rated 5 or 6 as being of high impact and, on that basis, specified a *Limit of visual pre-eminence* which was 16 kms for turbines 120 m high such that:

> "At this distance, the wind facility is a major focus of visual attention, drawing and holding visual attention. . . . The facility as a whole is likely to be perceived by some viewers as having a large visual impact." [13]

Within that range of visual pre-eminence, the threshold point from which the wind farm "dominated the view" was 6.4 kms[14].

Offshore Study

Argonne National Laboratories subsequently conducted a study on the visual impact of offshore wind farms[15]. It was done by a somewhat different group of researchers. As with the BLM study, this was commissioned by other US Government agencies.

The methodology was fairly similar to that of the BLM study and used the same rating scale. Observations were made from multiple viewpoints for 11 offshore wind farms in the UK, whose turbine heights ranged from 107m – 153m, averaging around 128m.

The study reported that:

> "The observed wind facilities were judged to be a major focus of visual attention at distances up to 16 km (10 mi)." [16]

> "Distance is indeed a prime determinant of visibility for a given design, size, and color of wind turbine"[17]

> "Analysis of the visibility rating data indicated very good agreement between the raters. In many cases, the observers gave identical numeric visibility ratings, and in the vast majority of cases with three observers, at least two of the three were in agreement. In only two cases [out of 38] did observers differ in their numeric rating by more than one point"[18]

> "At night, aerial hazard navigation lighting was visible at distances greater than 39 km (24 mi)."[19]

The Bishop Study

In 2002 Bishop published the results of laboratory research on the visibility of wind turbines. It was done simulating a single turbine on photographs of different backgrounds at various simulated distances and under various simulated conditions.

The images used in that study equated to a turbine height (63 m [20]) of slightly over half that of the actual ones observed in the BLM study, and less than half the height of what are now commonly proposed.

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[12] *BLM Study*, p. 4.
[13] *BLM Study*, p. 41.
[14] *BLM Study*, p. 40.
[15] Sullivan, Robert G., et. al., "Offshore Wind Turbine Visibility and Visual Impact Threshold Distances", *Environmental Practice* 15(01):33-49, March 2013 [***Offshore Study***].
[16] *Offshore Study*, p. 1.
[17] *Offshore Study*, p. 11.
[18] *Offshore Study*, p. 10.
[19] *Offshore Study*, p. 1.

In addition, the BLM study of real wind farms indicated one of the inherent weaknesses in the Bishop research. The BLM study found that:

> "In the authors' judgment, based on the many observations for this study, and comparison of the corresponding photographs and narrative records from the observations, the photographs consistently under-represent the degree of visibility observed in the field. While true to some degree for all of the photographs, this is particularly true for photographs of the facilities taken from longer distances." [21]

Similar observations were made in the University of Newcastle study and the Offshore study.

So there is a consistent, empirically observed effect that assessments based on photographs tend to underestimate turbine visibility. Yet even with this limitation, the Bishop study concluded "In areas with completely transparent skies, visibility modelling out to 20 km – 30 km is justified, but effects beyond 20 km may be rare and depend on exceptional viewing conditions."[22], and this for turbines less than half or even one third the size now routinely approved.

Zone of Visual Influence (ZVI)

The 2011 draft NSW Wind Farm Guidelines included the requirement that "The assessment should include . . . identification of the zone of visual influence of the wind farm (no less than 10km)" [23] with the clear implication that visual impact should be assessed within this zone. However, it did not define the term "zone of visual influence".

This is not uncommon. VI guidelines from various jurisdictions and research that use the term "zone of visual influence" generally don't specifically define it. However, the usage makes clear that they mean "the area within which the wind farm *may* have some material visual impact and which therefore need to be assessed".

Sometimes reference is made to a Zone of Theoretical Visibility (ZTV), whose meaning is clear from the words. Commonly the ZVI distance is less than the ZTV, since it is reasonably understood that an object at the limit of visibility will, by definition, normally have negligible visual impact. So the BLM study of wind farms with 120m turbines, stated[24] that "an appropriate radius for visual impact analyses would be 48 km", despite the fact that "The facilities were found to be visible to the unaided eye at >58 km (36 mi) under optimal viewing conditions".

Commonly, large parts of the area within a ZVI distance will have no view of the wind farm due to terrain or intervening structures. These can be readily and cheaply identified with available GIS software.

For all practical purposes, other parts will be locations where no one goes and will be fairly readily identified as such. That leaves wind farm proponents with the residual ZVI where viewers are exposed to the wind farm to some degree and for which the proponent needs to provide a justification for that impact (or delete particular turbines).

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[20] *University of Newcastle Study*, p. 13.
[21] *BLM Study*, p.43.
[22] Bishop, Ian D, 2002. "Determination of Thresholds of Visual Impact: The Case of Wind Turbines", *Environment and Planning B: Planning and Design* Vol. 29: p. 718.
[23] *Draft NSW Planning Guidelines Wind Farms*, December 2011, p. 4 and p. 18.
[24] *BLM Study,* p. 4.

There are obviously a number of arguments that might be advanced in justification. For instance:

- While the viewer can see some part of the wind farm, it is a sufficiently small part that at the distance of the viewer the visual impact is small; or
- Given the position of the viewer, the wind farm, and the background against which it is seen, it is not prominent; or
- Given the nature of the landscape, adding the wind farm has little adverse impact on the view; or
- The frequency with which anyone is going to see the wind farm from that viewpoint is so low it can be basically ignored.

It is not suggested that comments such as the above are valid in any particular situation but they are arguments that might plausibly be made in some situations. The important point is that within the ZVI it is incumbent on the wind farm proponent to substantiate such arguments wherever there are viewers and used viewpoints exposed to the wind farm.

Note, it is also not suggested here that because a viewpoint will suffer a serious visual impact from a wind farm that the wind farm must be prevented. That is the point at which planning authorities are engaged in a merit assessment to determine what is, on balance, the best thing to do. Such decisions might include mandating changes to the wind farm configuration, or compensation to the affected parties, or some mitigation method, or deciding that the visual impact, as identified, should be accepted.

The purpose of VI assessment is to judge the extent of actual impact. What, if anything, should be done about it is a separate matter and should not affect the judgment. It is similar to the situation when you visit a doctor. There is a diagnosis phase and a treatment phase. Obviously the treatment phase is strongly informed by the diagnosis, but the reverse should not apply. The fact that treatment may be very expensive, or risky, or uncertain or anything else should play no part in actually diagnosing the extent of the problem.

Of course it is not unheard of for parties responsible for treatment (be it governments or private insurers) to attempt to influence diagnosis processes to reduce the likelihood of diagnoses that will be expensive for them.

It would not be surprising in relation to wind farm policy to find parties with vested interests, be they government or wind farm developers, seeking to influence the diagnosis process to serve their interests. As a case of public policy development, we are interested in the extent to which those behaviours are discernable in the decisions of the NSW Government and Minister Stokes.

What the Empirical Research Established

Figure 1 shows a plot of ZVI thresholds for various turbine heights indicated by multiple research studies, and a line of best fit (excluding the BLM study which suggested a ZVI well above the line). Based on their observations, Thomas and Sinclair proposed ZVIs of 15 kms for 50m turbines and 30 kms for 100m turbines. It can be seen that those ZVIs lie almost exactly on the line derived from other studies.

Figure 2 shows plots of thresholds for visual dominance and pre-eminence based on empirical research studies. It can be seen that:

- The threshold distances given in the Sinclair-Thomas matrix for the most intrusive band (A), which the matrix describes as "***Dominant impact*** *due to large scale, movement, proximity and number*" align very closely with what other research has identified as the visually dominant threshold.
- Similarly the threshold distances given in the Sinclair-Thomas matrix for the second most intrusive band (B), which the matrix describes as "***Major impact due to proximity: capable of dominating landscape***" align very closely with what other research has identified as the visual pre-eminence threshold.

Finally, it is obvious from both Figure 1 and Figure 2, that combined research leaves no doubt that there is a strong relationship between turbine height and the extent of visual impact at any particular distance from the turbines, which was the central point developed in the formulation of the Sinclair-Thomas matrix based on their empirical observations.

In addition, the graphs show that the threshold distances are essentially linearly related to height. Double turbine height and the threshold distance doubles, whether it is for ZVI, pre-eminence or visual dominance.

A threshold distance marks the point beyond which a particular level of impact is unlikely to occur. Within the threshold distance (say for visual dominance) not every viewpoint will experience that same level of impact. Factors specific to each viewpoint come into play, such as number of turbines visible, elevation relation to the viewpoint, and typical atmospheric conditions.

The important point is that within the threshold distance every viewpoint has the potential to experience the specified level of impact (e.g. visual dominance) unless other factors intervene to cause a lower level of impact.

Therefore for each viewpoint within the threshold, the relevant VI cannot be assumed away. Its absence is a matter to be demonstrated in each instance, not assumed.

NSW Government Proposals in the Light of Empirical Research

In its draft VI Assessment Bulletin, the DPE introduced two lines. One set a threshold to be used in "pre-assessment" by wind farm proponents. It is the black line in Figure 1.

According to the draft VIAB, if any turbine is closer to a dwelling than that (black line) height-related threshold, then the proponent needs to consider possible impact as they develop their plans.

The second threshold is marked by the green line in Figure 1. The draft VIAB requires that for what the Bulletin deems the most sensitive viewing situations, if a turbine is closer than the green line threshold, the developer must provide justification. Note, they are not prohibited from placing turbines closer than that threshold – but must provide a justification.

Beyond that threshold there is no obligation to consider the impact of the wind farm or provide any justification.

Therefore effectively those two threshold lines become the ZVI to be applied. Notionally the black line is the ZVI to be used at pre-assessment stage and the green line the ZVI for the formal assessment. The draft VIAB does not refer to them as ZVI lines. If it did so the change from the

existing guidelines (ZVI minimum of 10 kms) would be too embarrassing. DPE simply stopped using the term ZVI.

What is patently obvious from Figure 1 is that these new, shrunken, ZVI lines are minute compared to where multiple empirical studies have determined they should be (the dotted line).

For a 50m turbine, the DPE green line sets the ZVI threshold at 1 km. The empirical research explicitly indicates a ZVI threshold of 15 kms for turbines that height. So the DPE proposed ZVI is ***one fifteenth (1/15 th)*** of what empirical research indicates. That same relationship (1/15 th) also applies at all other heights.

In practice the DPE proposal is even more inconsistent with research. The green line applies in full only to what the DPE VIAB deems the most sensitive viewing situations. For what are deemed less sensitive viewing situations (including most rural and rural residential dwellings) the ZVI effectively becomes a constant 2 kms or, in many instances, 1 km.

Thus the DPE has proposed a ZVI (which it now refuses to call by that name) that is at most only 1/15 th of the research-based ZVI distance and in many cases much less than that.

Figure 2 makes even clearer why the DPE's suggestion is intellectually indefensible. That diagram includes the DPE's green line (for formal assessment) threshold. It also includes two other thresholds defined by empirical research and, for each, shows the individual points determined by the various studies.

The dotted blue line marks the threshold for *visual pre-eminence* (the term defined in the BLM study). The dotted red line is the threshold for *visual dominance*.

As can be seen, DPE's ZVI threshold is set at about 1/6 th of the threshold for *visual pre-eminence* and about 40% of the threshold for *visual dominance*.

People might reasonably ask:

> "On what basis is it reasonable to allow a developer to ignore the VI on dwellings and other important viewpoints through ***5/6 ths of the range*** where the wind farm can be visually pre-eminent unless obstructed?"
>
> and
>
> "On what basis is it defensible to allow a developer to ignore the VI on dwellings and other important viewpoints through ***60% of the range*** where wind farms can be visually dominant?"

Once again it needs to be noted that DPE's proposed green line threshold applies in full only for what DPE considers the most sensitive viewing situations, which excludes most rural and rural residential dwellings. In the latter cases, where the threshold becomes a flat line at either 2 kms or 1 km, anywhere ***from 75% to 90% of the distance within the visually dominant threshold may be ignored by the developer***.

It is worth looking at some specific cases to see how the DPE's recommendations and proposals compare with the actual empirical research.

Actual Cases with DPE Decisions and Recommendations in Light of the Research

For the ***Sapphire wind farm*** the NSW Government has approved ***200m*** turbines. The proposed ***Bango wind farm*** seeks approval for ***200m*** turbines. The empirical research indicates that for turbines of that height:

- the threshold for visual dominance is about 11 kms;
- the threshold for visual pre-eminence is over 20 kms and the appropriate ZVI is even greater.

Yet DPE's line beyond which justification is not necessary (i.e. effectively ZVI) is at most 4 kms for turbines of that height and in reality 2 kms or even 1 km, since the line applies only to what DPE regards as the most sensitive viewing situations which does not include rural and rural residential dwellings beyond one or the other of 1 and 2 kms.

On DPE's recommendation, the PAC approved ***160m*** turbines for the ***Crudine Ridge wind farm***. For that height, the empirical research indicates:

- the threshold for visual pre-eminence is 20 kms;
- the threshold for visual dominance is about 8 kms.

Yet DPE, in its submission to the PAC, claimed:

> "The Department considers that beyond 3 km from the nearest turbine, it is unlikely that the wind turbines would dominate the landscape and/or have significant visual impacts."[25]

The Department's officials offer no empirical support for this statement. All the relevant research had been published at the time this statement was made by the officials. **Note** 3 kms is essentially the distance given by the green "justification" line in the VIAB for 160m turbines, as can be seen from Figure 2. So the officials were making a claim which would seem to be either based on the line or gave rise to it.

Certainly the concept of a threshold allows for the fact that within the threshold some viewpoints may not experience a dominant or pre-eminent visual impact, due to factors such as obstruction.

Yet in the same assessment report, the officials refer to:

> "residence SRF11, which despite being located 3.26 km from the nearest wind turbine, would potentially have views of up to 80% of the project wind turbines" [26]

So obviously that residence is not shielded from most of the wind farm. It is therefore well within the threshold for visual dominance and since it would see most of the wind farm the empirical research indicates that there will be a dominant visual impact despite the personal claims by the Department's officials.

It is clear DPE's thresholds are wholly **invalidated** by **all** the wind farm VI research. ***There is no research that provides any support for what DPE has suggested as a ZVI threshold*** (while calling it something different).

[25] *Crudine Ridge Assessment Report*, Department of Planning & Environment, December 2015, p. 33.
[26] *Crudine Ridge Assessment Report*, Department of Planning & Environment, December 2015, p. 33.

Figure 1

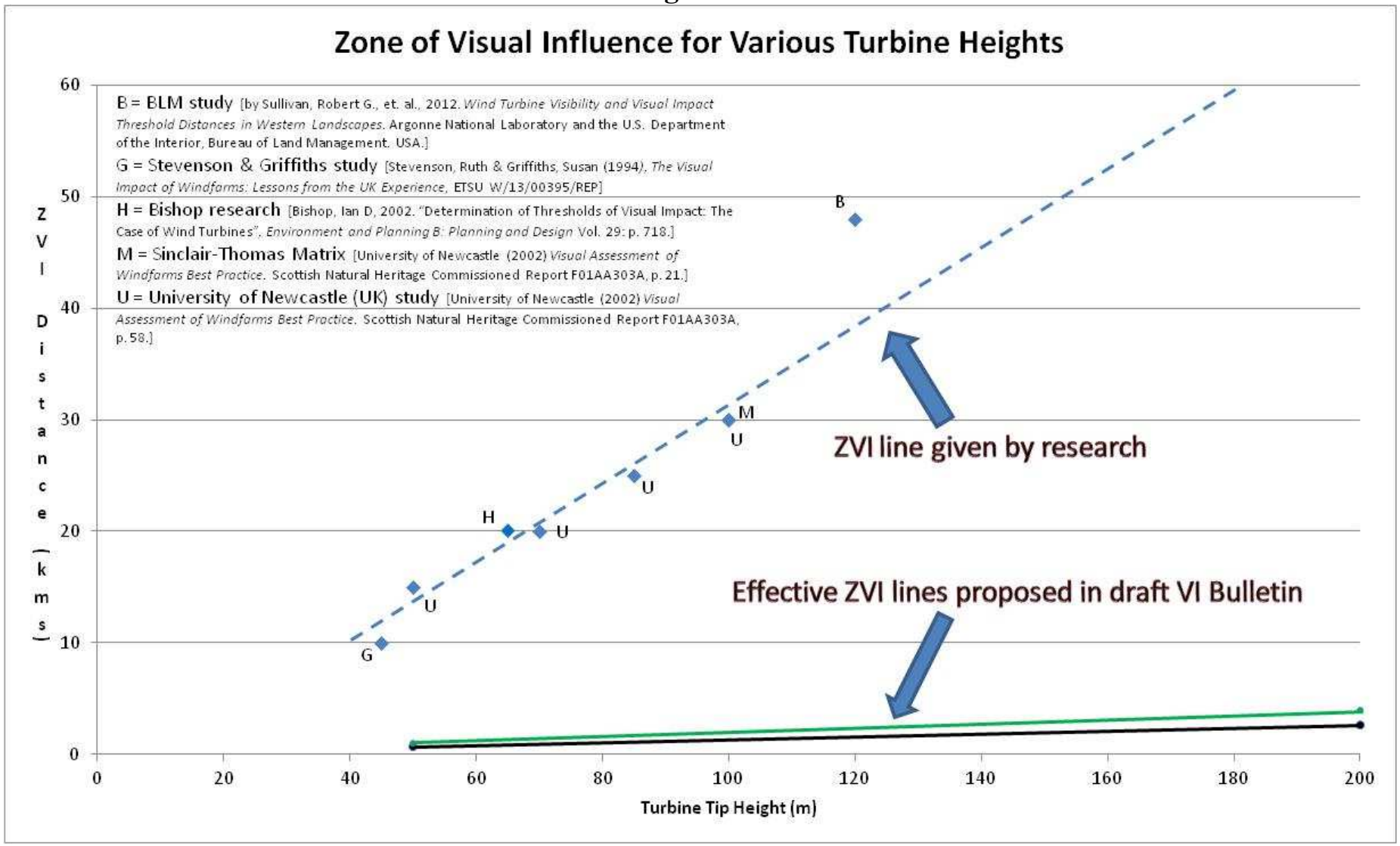
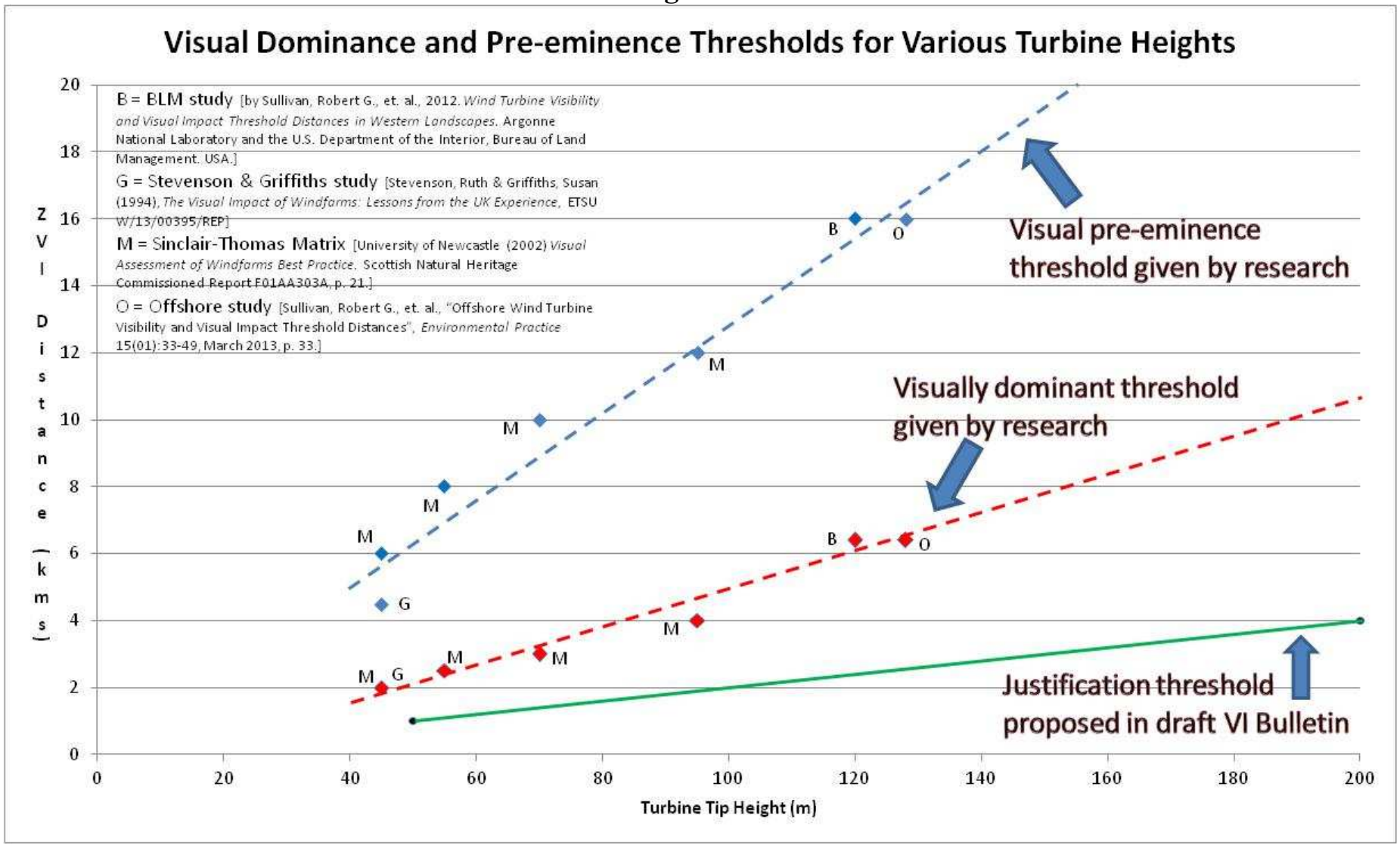

Zone of Visual Influence for Various Turbine Heights
B = BLM study [by Sullivan, Robert G., et. al., 2012. Wind Turbine Visibility and Visual Impact Threshold Distances in Western Landscapes. Argonne National Laboratory and the U.S. Department of the Interior, Bureau of Land Management. USA.]
G = Stevenson & Griffiths study [Stevenson, Ruth & Griffiths, Susan (1994). The Visual Impact of Windfarms: Lessons from the UK Experience, ETSU W/13/00395/REP]
H = Bishop research [Bishop, Ian D, 2002. "Determination of Thresholds of Visual Impact: The Case of Wind Turbines". Environment and Planning B: Planning and Design Vol. 29: p. 718.]
M = Sinclair-Thomas Matrix [University of Newcastle (2002) Visual Assessment of Windfarms Best Practice. Scottish Natural Heritage Commissioned Report F01AA303A, p. 21.]
U = University of Newcastle (UK) study [University of Newcastle (2002) Visual Assessment of Windfarms Best Practice. Scottish Natural Heritage Commissioned Report F01AA303A, p. 58.]
ZVI Distance (kms)
Turbine Tip Height (m)
ZVI line given by research
Effective ZVI lines proposed in draft VI Bulletin
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160
180
200
B
M
U
U
H
U
U
G

Figure 2


Visual Dominance and Pre-eminence Thresholds for Various Turbine Heights
B = BLM study [by Sullivan, Robert G., et. al., 2012. Wind Turbine Visibility and Visual Impact Threshold Distances in Western Landscapes. Argonne National Laboratory and the U.S. Department of the Interior, Bureau of Land Management. USA.]
G = Stevenson & Griffiths study [Stevenson, Ruth & Griffiths, Susan (1994), The Visual Impact of Windfarms: Lessons from the UK Experience, ETSU W/13/00395/REP]
M = Sinclair-Thomas Matrix [University of Newcastle (2002) Visual Assessment of Windfarms Best Practice, Scottish Natural Heritage Commissioned Report F01AA303A, p. 21.]
O = Offshore study [Sullivan, Robert G., et. al., "Offshore Wind Turbine Visibility and Visual Impact Threshold Distances", Environmental Practice 15(01):33-49, March 2013, p. 33.]
Visual pre-eminence threshold given by research
Visually dominant threshold given by research
Justification threshold proposed in draft VI Bulletin
ZVI Distance (kms)
Turbine Tip Height (m)
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200

Other Important Empirical Findings

In addition to elucidating the real relationship between turbine height and VI, the empirical research has provided a number of other findings important to wind farm VI and the assessment of prospective VI:

- Blade movement increases the VI of turbines compared to a static structure of comparable dimensions.
- Because of the anomalous visual effect of blade movement from partially obscured wind turbines, their VI may be much greater than would be expected for the physical amount of turbine visible.
- Photographs and photomontages significantly and systematically underestimate the visibility of wind farms compared to field observations.
- Assessment frameworks using a 3x3 matrix are too simplistic to capture real world wind farm VI.

Blade Movement

Most of the empirical studies on wind farm VI explicitly refer to the importance of blade movement in determining the visibility and VI of wind turbines and, by implication, the inadequacy of static images to represent VI. Thus the BLM study reported:

> "In the intermediate area, wind turbines would dominate the space because of their height and their movement. In the immediate area, wind turbines would be extremely dominant because of their size and the rotational movement of the blades (Jallouli and Moreau, 2009; University of Newcastle, 2002)."[27]
>
> "Additional research has been conducted to determine the influence of wind turbine blade movement in conjunction with distance. In general, the human eye can detect movement at large distances. The rotary and very regular movement of wind turbine blades is not a common type of "natural" movement, especially at the scale of a large wind facility. Instead, this type of movement has been found to be highly noticeable" [28]
>
> "At times, the blades may not be visible, but a slight "pulse" in the intensity of light can be seen as the blade passes across the wind turbine tower (Coates Associates, 2007)." [29]
>
> "The prevalence of lower visibility ratings for observations where blades and blade movement were not visible, even at relatively short distances, suggests that blade/blade movement visibility may be an important driver of the overall visibility of wind facilities." [30]

The Offshore study reported:

> "As will be shown, the findings of our present study suggest that the actual distance for blade movement visibility is much greater than was indicated in these previous studies." [31]
>
> "The synchronized sweeping movement of the massive blades during the day and the synchronized flashing of the lighting at night contribute to the facilities' visibility over very long distances." [32]
>
> "Turbine blade movement was visible at distances as great as 42 km (26 mi) in 42 of the 49 daytime observations (Gunfleet Sands, Viewpoint V25, elevation 47 m) and was observed routinely at distances

[27] *BLM Study*, p. 11.
[28] *BLM Study*, p. 12.
[29] *BLM Study*, p. 13.
[30] *BLM Study*, p. 21.
[31] *Offshore Study*, p. 5.
[32] *Offshore Study*, p. 2.

> of 34 km (21 mi) or less. Contrary to expectations, lighting conditions, sun angle, and apparent contrast between the turbines and the sky backdrop did not substantially affect the likelihood of observing blade motion; blade motion was visible at distances beyond 30 km (19 mi) regardless of sun angle, lighting conditions, or contrast levels. Again, these distances are greater than those reported in previous studies." [33]

The University of Newcastle study reported:

> "The movement of the blades, in all cases where this is visible, increases the visual effect of the turbines because it tends to draw the eye." [34]
>
> "we judge that blade movement is perceptible to the casual observer at up to approximately 10 km." [35] ***Note. This observation was for turbines mainly around 65m to tip height.***

In addition, the University of Newcastle study reported:

> "The appearance of just the rotors, or the nacelle and rotors, above the horizon produces a disconcerting effect when they are moving that we would describe as less visually coherent" [36]

This last point is important because there is a tendency in VI assessments to discount the VI of turbines that are partly obscured from a viewpoint. The partly obscured turbine may appear to have less VI in a photo but the University of Newcastle study tells us it may not be less in the real world because of the perceptual impact of the anomalous movement when only part of the blade motion is visible.

Systematic Underestimation of VI using Photographs and Photomontages

Wind farm VI assessments generally depend on photomontages to display the purported visual scene after the wind farm is constructed. Consultants and planning officials then rely heavily on those images to make judgements about the magnitude of visual impact that will occur.

There are ways those images can be constructed to deliberately mislead. Scottish Natural Heritage has produced detailed advice[37] about how they should be produced in order to avoid artifactual distortions.

Importantly, the empirical research findings show that even if photomontages are prepared scrupulously, the result still systematically underestimates the VI compared to what will be experienced by someone looking at the real wind farm.

The University of Newcastle study reported:

> "We found that there was a general tendency to underestimate the magnitude of visibility in the ES descriptions compared to our judgements on site. This may be related to the frequent under-representation seen in photomontages" [38]
>
> "A photomontage can imply a degree of realism that may not be robust, and can seduce even a critical viewer into investing more faith in that realism than may be warranted. Certainly our case-study analyses confirm a widespread belief that photomontages almost always underestimate the true

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[33] *Offshore Study*, p. 12.
[34] *University of Newcastle Study*, p. 52.
[35] *University of Newcastle Study*, p. 52.
[36] *University of Newcastle Study*, p. 52.
[37] *Visual representation of windfarms: good practice guidance*, Scottish Natural Heritage, 2006 and *Visual Representation of Wind Farms, Version 2*, Scottish Natural Heritage, July 2014.
[38] *University of Newcastle Study*, p. 55.

> appearance of a windfarm from most viewpoints. This is in contrast to statements in some ESs that overestimation occurs because of the technique used to produce the photomontage." [39]

The BLM study report stated:

> "In the authors' judgment, based on the many observations for this study, and comparison of the corresponding photographs and narrative records from the observations, the photographs consistently under-represent the degree of visibility observed in the field. While true to some degree for all of the photographs, this is particularly true for photographs of the facilities taken from longer distances." [40]

and the Offshore study reported:

> "Our informal, qualitative opinion is that the photographs taken in the field generally show lower visual contrast levels than were actually observed during the visibility ratings. The photographs show lower contrast and less detail than was actually apparent in the naked-eye observations, and they do not capture the blade motion that attracted the visual attention of observers in the field." [41]

In the BLM and Offshore studies the researchers compared their own observation of the scenes with photographs they took at the time. In the University of Newcastle study the comparison was between the researchers' observation of the scenes and photomontages which had been prepared before the wind farms were built.

In all cases they concluded the photographs under-estimated the impact. Two factors in particular contributed. First, the photographs show lower contrast and less detail than was actually apparent in the naked-eye observations. Second, they lack motion, which as the research showed is a very important factor affecting the visibility of wind turbines. In addition the University of Newcastle study pointed to some instances where the photomontage preparation was well short of best practice.

Given that the issue identified by these studies is systematic, planning authorities should consider photomontages with the knowledge that they almost invariably significantly under-state what will be the visibility and VI of the wind farm once constructed. That requires a conscious effort for planners to acknowledge this problem and explicitly view all photomontages, and assessments derived from them, on that basis.

Assessment Methodology

Based on their empirical observations, the studies also made some comments highly relevant to VI assessments and how they are presented.

The University of Newcastle study reported:

> "The LI-IEA (1995) model matrix of three classes on each axis producing 9 cells, only 3 of which are typically judged as significant, is in our view simplistic and unrefined and quite unsuitable as a tool for widespread use. In particular it implies a degree of certainty about a very restricted definition of significance that we do not believe is justified. Expanding a 3 x 3 (9 cells) matrix to 4 x 4 (16 cells) or even 5 x 5 (25 cells) is much more representative of the diversity of size and sensitivity found in visual impact assessment." [42]

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[39] *University of Newcastle Study*, p. 60.
[40] *BLM Study*, p.43.
[41] *Offshore Study*, p. 45.
[42] *University of Newcastle Study*, p. 64.

Note. The matrix referred to above has two dimensions, one magnitude of visual effect and the other for "sensitivity" to visual intrusion, for each of which a 3 point scale was used. This is a framework which, in some form or other, is frequently used in VI assessments. The University of Newcastle study explicitly found that the gradations possible with 3 point scales is inadequate to provide the granularity necessary to reasonably describe real world situations.

The BLM and Offshore studies both used a 6 point scale for visibility. The Sinclair-Thomas matrix is a 9 point scale. Stevenson & Griffiths used 4 categories for levels of visibility. The studies, and the explicit comments from the University of Newcastle study make clear that the 3 point scales and the 3x3 matrix often used in Australian wind farm VI assessments are inadequate and therefore assessments presented using that methodology are misleading.

The University of Newcastle makes another important statement:

> "This may also be an appropriate point to raise a subtle presentational point about visibility assessment. Because many factors act to decrease or increase apparent magnitude (and therefore potential significance), there is a tendency in all the ESs examined (and in guidance such as is shown in Table 3) to adopt what might be termed the "half-empty" rather than the "half-full" approach to assessment. For example, guidance and assessment often emphasises the factors that decrease visibility ("only prominent in clear visibility") rather than the factors that increase visibility ("always prominent in clear visibility"). Although both statements are in one sense identical, a different adverb produces a different impression." [43]

In other words consultants' assessments are frequently written as advocacy not as impartial professional assessments and planning authorities need to identify wording that is meant to convey a skewed representation of the situation and discount it.

Wind Farm Size

There appears to be no demonstrable relationship, across the various studies, between wind farm size (number of turbines) and empirical VI. That is not surprising. Any effect due to number of turbines would surely be related to the number of turbines visible from a viewpoint, not the total number of turbines in the wind farm. The number of turbines visible at any viewpoint in the studies was often less than the whole wind farm, which is quite common.

However, some of the comments in the studies make clear that a large number of turbines is not necessary to create a strong VI. For instance, the Offshore study (with turbines averaging 128m) reported:

> "small to moderately sized facilities were visible to the unaided eye at distances greater than 42 km [26 miles (mi)]" [44]

> "At distances of 14 km (9 mi) or less, even isolated, small facilities will likely be a major focus of visual attention in seaward views, again in a variety of weather and lighting conditions." [45]

It is reasonable to suppose that the extent of VI is at least in part dependent on the number of turbines visible. It is also reasonable to expect a declining marginal impact from each additional turbine at a constant distance. In other words, if there are already 20 turbines in view, adding a twentyfirst will have much less ***additional*** impact than adding a second when otherwise only one

[43] *University of Newcastle Study*, p. 55.
[44] *Offshore Study*, p. 1.
[45] *Offshore Study*, p. 14..

turbine was in view. And the impact of a second turbine will generally be less than that of the first wind turbine in a view.

Naturally this is not suggesting the VI of 20 turbines will be less than that of a single turbine. The comment refers to the ***incremental*** impact of adding a single turbine, where that incremental VI will become less the more turbines are already present.

Summary

There is now a substantial body of empirical research by very credible teams on wind farm visual impact (VI). That research shows a consistent and essentially linear relationship between turbine height, distance and wind farm VI. For any degree of VI (such as the zone of visual influence, or threshold for visual dominance), if turbine height is doubled, the distance threshold point for that degree of impact also typically doubles.

The research based distances for thresholds for key levels of VI (ZVI, visual pre-eminence, visual dominance) are many times larger than thresholds proposed by the NSW Department of Planning and Environment in its draft VI Assessment Bulletin. In fact for ZVI, the research derived distance for any turbine height is about ***fifteen (15)*** times larger than the equivalent threshold proposed in the VI Assessment Bulletin.

There is no empirical research substantiation for the DPE proposed threshold distances. They are, in fact, repudiated by the research.

The research also has revealed several other points important for wind farm VI assessment.

- Blade movement significantly increases the VI of turbines compared to a static structure of comparable dimensions.
- Photographs and photomontages materially underestimate the visibility of wind farms compared to field observations of actual wind farms. This is due to both the absence of movement, which is so important in drawing attention, and the fact that the photographic process inherently does not fully reflect human perception of a scene.
- Because of the anomalous visual effect of blade movement from partially obscured wind turbines, their VI may be much greater than would be expected for the physical amount of turbine visible.
- Assessment frameworks using a 3x3 matrix to represent VI, which are common in wind farm assessments, are too simplistic to capture real world wind farm VI and thus misleading.

If public policy ignores relevant consistent, empirical research, the result is arbitrary and unjust policy. There is nothing in the DPE VI Assessment Bulletin which discusses and attempts to come to grips with the research now available, nor to attempt to justify the Bulletin's proposals in the context of the research findings.

Because of the failure to do so, the public might reasonably conclude the proposals are simply whims of government officials or, if not whims, specifically crafted to serve the interests of wind farm developers who would make much less money under policy that aligned more closely with the published research.

The NSW Government has a responsibility to reassess its draft VI Assessment Bulletin explicitly in the context of the published research and produce proposals which it can intellectually justify in the context of that research.